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Published version

OJEDOKUN, Olalekan, ADENIRAN, A.A., RAHEEM, S.B. and ADERINTO, S.J. (2014). Cow Dung Ash (CDA) as Partial Replacement of Cementing Material in the Production of Concrete. *British Journal of Applied Science & Technology*, 4 (24), 3445-3454.

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Cow Dung Ash (CDA) as Partial Replacement of Cementing Material in the Production of Concrete

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Authors' contributions

This work was carried out in collaboration between all authors. Author OYO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors AAA, SBR and SJA managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

Original Research Article

Received 17th August 2013
Accepted 17th October 2013
Published 27th June 2014

ABSTRACT

This research project presents the result on the study for the use of Cow Dung Ash (CDA) as partial replacement in production of concrete. The experiments were designed to study the effects of adding Cow Dung Ash (CDA) in various percentages by weight (10%, 20% and 30%) of cement and cure for the periods of 7, 14, 21 and 28, days respectively before testing for the Compressive strengths.

It also involves determination of setting time, Bulk Density, and Workability of Cow Dung Ash in various percentages by mixing with Portland cement.

The Compressive test results are 21.33 N/mm³, 21.11 N/mm³, 11.11 N/mm³ and 6.00 N/mm³ for 0%, 10%, 20% and 30% replacement of cement with CDA respectively at 28 days. The Workability results gives 40mm, 48mm, 80mm and 100mm respectively for 0%, 10%, 20% and 30% replacement of cement with CDA.

Among the main conclusions, it should be highlighted that the initial and final setting time increases as the percentage of Cow Dung Ash is added, (CDA) has an advantage that offers lightness of weight and low thermal conductivity, Cow Dung Ash requires more quantity of water as the percentage increases in the concrete therefore it has a serious limitation that must be understood before it is put to use. Cow Dung Ash concrete is recommended for use only when a ten percentage (10%) of Cow Dung Ash is added.

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While the concrete is suitable for use on certain floor and wall that will not be subjected to heavy load or structures that are of temporary use (CDA) concrete is not to be used in a water accumulated area or for structures that are related to water.

Keywords: Cow dung ash (CDA); compressive test; setting time; bulk density; workability.

1. INTRODUCTION

It is well accepted by everyone that concrete executes outstanding responsibilities for the construction of modern infrastructures and industrialization [1]. Attempt has been made by various researchers to maintain the durability, strength and stability of concrete structure while also reducing the cost of production. The cement industry has one of the highest carbon footprints which make traditional concrete unsustainable in the future. Materials such as Cow Dung Ash, Fly Ash, Slag, and Silica Fume, can be used as partial replacement for cementing material [2]. Cow Dung Ash is obtained from cow excreta which is dried by sunlight and subjected to burning as a result, ash is obtained in black colour. It is bulky and has a large ash content containing a Nitrogen rich material, Potassium, Phosphorous and Calcium [3].

Cow dung is basically the rejects of herbivorous matter which is acted upon by symbiotic bacteria residing within the animal's rumen. Cow/Cattle are mostly found in every part of Nigeria while they are mostly rear in the northern states of the nation such as Plateau state, Nassarawa state, Kaduna state, Jigawa state, e.t.c. [4]. Cow dung comprises of organic matter including fibrous material that passed through the cow's digestive system, among other liquid digesta that has been left after the fermentation, absorption and filtration, then acidified, then absorbed again. Exact chemical composition is of mostly carbon, nitrogen, hydrogen, oxygen, phosphorus, etc. with salts, cells sloughed off as the digester went through the digestive tract, some urea, mucus, as well as cellulose, lignin and hemicellulose. [5].

Cow dung was habitually used in concrete and so one may suppose there were particular benefits in its inclusion. Recent publications suggest that dung may improve workability and durability or may act as an additional binder. Knowledge has also been lost as to whether fresh, old or weathered dung was used. Since there is no historic reference to the dung being old or weathered, it is conceivable that this is a recent invention resulting from modern attitudes toward odour and hygiene. In any case, dried and fresh dung differ mainly in the water content and so are likely to affect only the amount of water, if any, added during mixing of the concrete. This illustrates the literature of the active cow dung component in concrete.

2. MATERIALS AND METHODS

2.1 Processing of Cow Dung Ash

Cow dung ash has chemical properties rich in Nitrogen, Potassium and calcium. It has relatively high carbon to the Nitrogen ratio. While it has physical properties such as it is bulky, has large ash content and burning ratio is low. The ones used for this project work is obtained from Bodija abattoir, Ibadan, Oyo state, Nigeria. The cow dung is exposed to

sunlight to dry in order to have dung cakes which is then subjected to burning after it is dried to have the cow dung ash which is obtained in black colour.

2.2 Laboratory Tests

The following laboratory tests were carried out on percent mix for 0%, 10%, 20% and 30% replacement of cement with CDA respectively:

- a. Sieve analysis test
- b. Bulk Density
- c. Compressive cube test
- d. Workability test

a. Sieve Analysis Test: Sieve analysis test is the separation of aggregate into fraction. Each fraction consists of particles with specific limit, these being openings of standard test sieves. The CDA was placed in BS sieve which has sieves mount in frame so that they are place on one above the other with large sieve size at the top and the smallest at the bottom. The material is poured from the top and the sieve is given a vigorous shake mechanically. After shaken the material retained on BS sieve represent the function of the fine aggregate.

b. Bulk Density: The CDA aggregate are gently lowered into the metal mould to over flow and then level rolling a rod across the top to level it. Care is taken as far as possible segregation of the size of the sample is compacted. The net weight of the aggregate in the mould is use to determine the density in kg/m^3 . The bulk density by this method is loose or uncompacted density.

c. Compressive Cube Test: Steel mould of cast iron of dimension 150mm x 150mm x 150mm is used for casting a total of 16 concrete cubes of 0%, 10%, 20% and 30% percent replacement of cement with CDA respectively. The mould and its based are rigidly clamped together so as to reduce leakage during casting. The sides of cube are thinly oiled before casting so as to prevent the development of bond between the concrete and the mould [6]. Stipulates that the cubes should be filled in three layer is compacted by 25 strokes of 25mm square inches steel. The ramming is done efficiently to ensure full compaction. The cubes are cleaned of excess concrete by passing an iron in a sawing motion over the top of the cubes. The free surface is finish using hand trowel. The cubes are stored 24 hours undisturbed at temperature 18°C to 22°C and relative humidity of not less than 90 percent. The mould is stripped off after 24 hours and the cubes are to be stored in water for curing in a curing tank at 19°C to 21°C [7].

At the end of the test the cubes are crushed with the crushed faces in contact with the platens of the testing machine [8]. States that the load on the cubes can be applied at the rate of $15\text{N/mm}^2/\text{min}$. The rate of increase in strain is progressively increased as failure is approached. This is due to the non-linearity of the stress- strain relationship for the concrete at high stress. The strength at failure is reported to the nearest 0.5N/mm [9].

d. Workability: [10] Defines workability as the ease with which a concrete mix can be handle from the mixer to its finally compacted shape. Measurement of workability can be through slump test, compacting factor test, veebe time test, for this research, slump test was adopted because it is the most suitable for quality control purpose. The slump cone was held down against it base with the small opening at the top. It was filled with the fresh

concrete in the three layers being tampered 25 times with the help of a standard 16mm diameter steel rod rounded at the bottom end. The top of the cone was struck off with a trowel and the spilt concrete around the base of the cone was cleaned off. The cone was lifted slowly, the reduction in height (slump) between the cone mould and carried concrete mould were measured.

3. RESULTS AND DISCUSSIONS

3.1 Bulk Density Results

Below Tables 1-4 express the results as obtained before and after crushing the cubes. The curing days for the cubes are 7, 14, 21 and 28 days respectively. Table 5 shows the results obtained for density of cubes for each curing periods which reveals the highest density at 28 days of 0% Cow Dung Ash while the least dense cube is at 7 days of 0% Cow Dung Ash.

The Density of the cubes decreases as the percentage content of Cow Dung Ash increase; this reveals that the lightness in weight of specimen is due to the presence of CDA and the higher the percentage of CDA the lighter the specimen. Also, the result reveals that the Density of specimen increases with age. Figs.1 & 2 below clearly shows the pattern of the Density of Cubes with various percentages of Cow Dung Ash against curing time, The Density of Cube is highest at 28 days with 2,755.60kg/m³ while the lowest Density is recorded at 7 days with 2,373.3 kg/m³.

Table 1. Density of cubes at 7 days (12 – 06 – 2013)

Specimen	Crushing load (kN)	Crushing strength (kN/mm ²)	Density of cube (kg/m ³)
0%	325	14.44	2,488.9
10%	305	13.56	2,459.3
20%	150	6.67	2,414.8
30%	115	5.11	2,373.3

The Density of the cubes is low due to the number of curing days.

Table 2. Density of cubes at 14 days (19 – 06 – 2013)

Specimen	Crushing load (kN)	Crushing strength (kN/mm ²)	Density of cube (kg/m ³)
0%	350	15.56	2,577.80
10%	342	15.20	2,533.30
20%	208	9.24	2,370.40
30%	122	5.42	2,311.11

The Density of the cubes increases compare to the 7 days curing.

Table 3. Density of cubes at 21 days (26 – 06 – 2013)

Specimen	Crushing load (kN)	Crushing strength (kN/mm ²)	Density of cube (kg/m ³)
0%	392	17.42	2,637.00
10%	385	17.11	2,577.80
20%	228	10.13	2,311.11
30%	130	5.78	2,207.40

There is an increase in the Density of the cubes compare to the 14 days.

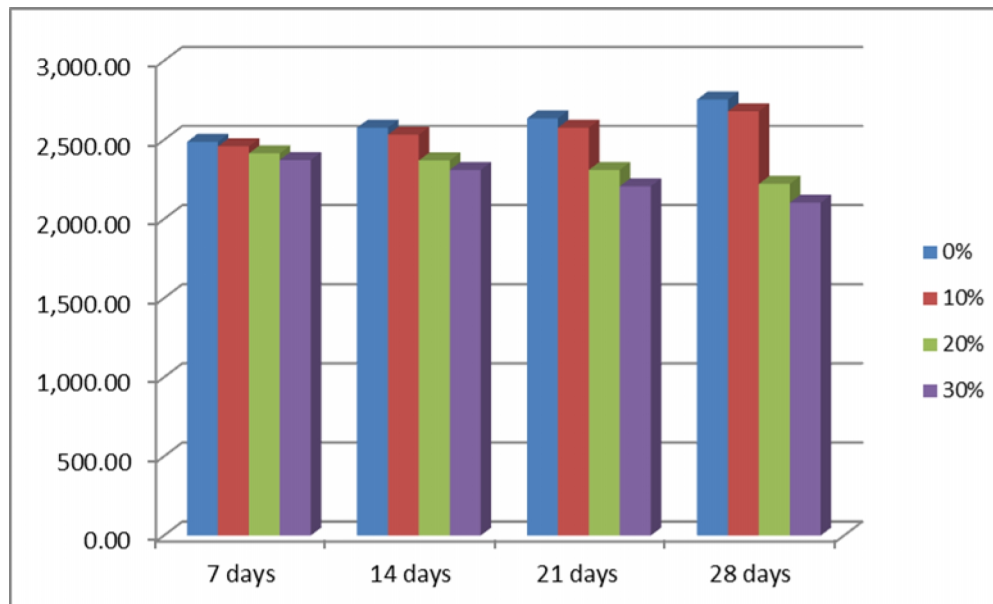
Table 4. Density of cubes at 28 days (03 – 07 – 2013)

Specimen	Crushing load (kN)	Crushing strength (kN/mm ²)	Density of cube (kg/m ³)
0%	480	21.33	2,755.6
10%	475	21.11	2,681.5
20%	250	11.11	2,222.2
30%	135	6.00	2,103.7

This also increases compare to previous number of curing days.

Table 5. Results obtained for density of cubes for each curing periods

Curing period	0%	10%	20%	30%
7 days	2, 488.90	2, 459.30	2,414.80	2,373.30
14 days	2, 577.80	2, 533.30	2, 370.40	2,311.11
21 days	2, 637.00	2, 577.80	2, 311.11	2,207.40
28 days	2, 755.60	2, 681.50	2, 222.20	2,103.70

**Fig. 1. Bar chart representation of density of cubes against curing periods**

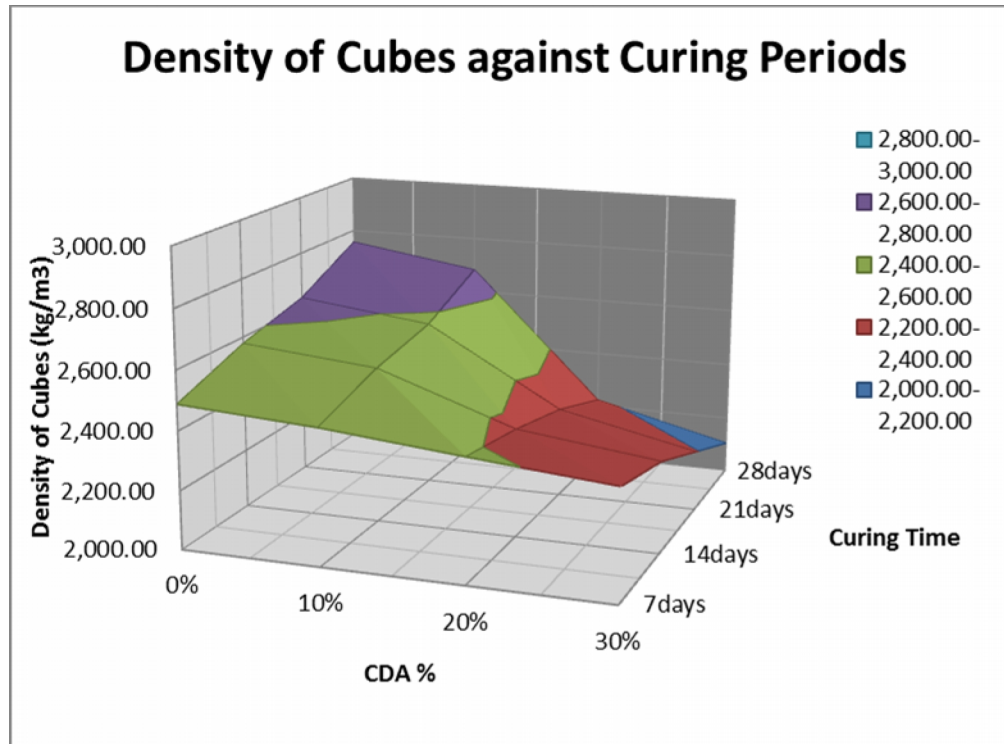


Fig. 2. Surface plot representation of density of cubes against curing periods

3.2 Compressive Cube Results

The following Tables 6-9 shows a detailed result presentation of the research work after the practical and laboratory test. See as follows per the curing days of 7, 14, 21 and 28 days respectively. The introduction of 10% Cow Dung Ash has a slight lower value to the control specimen while 30% replacement by CDA has a wide range of value to the control specimen. The Cube Strength reduces as the percentage of Cow Dung Ash increases, this is a clear indication that further introduction of percentage of CDA beyond 10% will greatly affect its Strength properties of the specimen negatively. Table 10 shows the results obtained for cube strength for each curing periods with the highest value recorded at 28 days of 0% Cow Dung Ash while the lowest value is at 7 days of 30% Cow Dung Ash. Fig. 3 below clearly shows the pattern of the Cube Strength with various percentages of Cow Dung Ash against curing time, the Cube Strength is highest at 28 days with 21.33N/mm² while the lowest Cube Strength is recorded at 7 days with 5.11 N/mm².

Table 6. Cube strength of CDA varying the percentage for replacement of cement at 7 days of curing

% CDA in cement	Cube sizes (mm ²)	Cube area (mm ²)	Water/ cement	Weight of cube (kg)	Density of cube (kg/mm ³)	Crushing load (kN)	Cube strength (N/mm ²)
0%	150mm x 150mm	22500	0.5	8.38	2,488.90	325	14.44
10%	150mm x 150mm	22500	0.5	8.3	2,459.30	305	13.56
20%	150mm x 150mm	22500	0.5	8.15	2,414.80	150	6.67
30%	150mm x 150mm	22500	0.5	8.01	2,373.30	115	5.11

Table 7. Cube strength of CDA varying the percentage for replacement of cement at 14 days of curing

% CDA in cement	Cube sizes (mm ²)	Cube area (mm ²)	Water/ cement	Weight of cube (kg)	Density of cube (kg/mm ³)	Crushing load (kN)	Cube strength (N/mm ²)
0%	150mm x 150mm	22500	0.5	8.700	2,577.8	350	15.56
10%	150mm x 150mm	22500	0.5	8.550	2,533.8	342	15.2
20%	150mm x 150mm	22500	0.5	8.000	2,370.4	208	9.24
30%	150mm x 150mm	22500	0.5	7.800	2,311.11	122	5.42

Table 8. Cube strength of CDA varying the percentage for replacement of cement at 21 days of curing

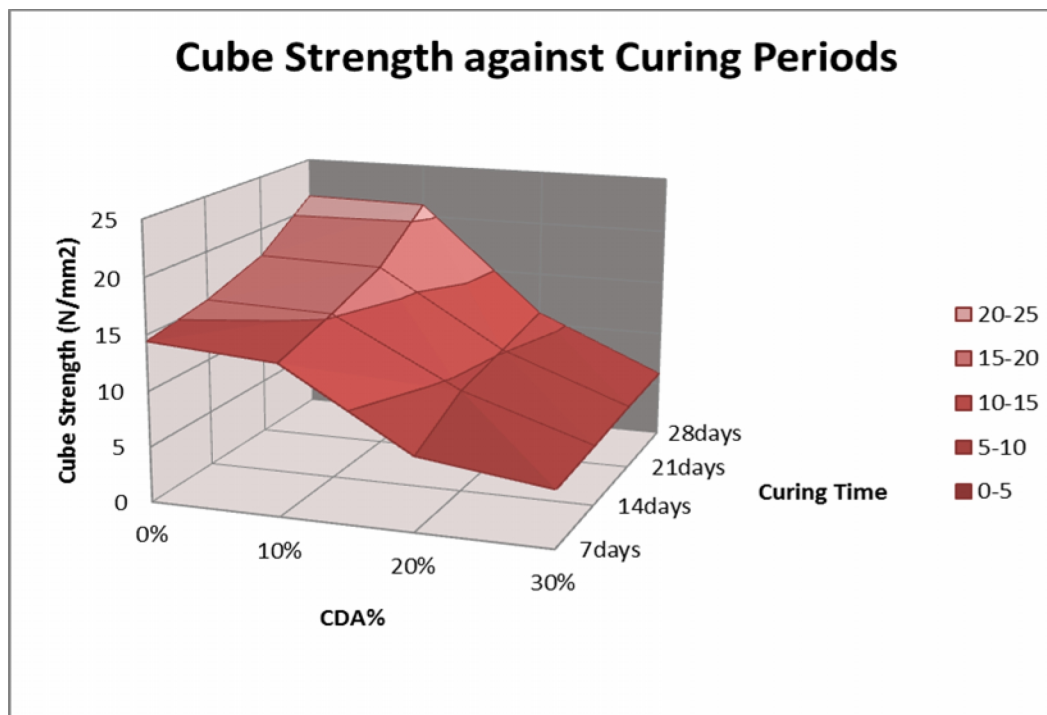
% CDA in cement	Cube sizes (mm ²)	Cube area (mm ²)	Water/ cement	Weight of cube (kg)	Density of cube (kg/mm ³)	Crushing load (kN)	Cube strength (N/mm ²)
0%	150mm x 150mm	22500	0.5	8.900	2,637.0	392	17.42
10%	150mm x 150mm	22500	0.5	8.700	2,577.8	385	17.11
20%	150mm x 150mm	22500	0.5	7.800	2,311.11	228	10.13
30%	150mm x 150mm	22500	0.5	7.450	2,207.4	130	5.78

Table 9. Cube strength of CDA varying the percentage for replacement of cement at 28 days of curing

% CDA in cement	Cube sizes (mm ²)	Cube area (mm ²)	Water/ cement	Weight of cube (kg)	Density of cube (kg/mm ³)	Crushing load (kN)	Cube strength (N/mm ²)
0%	150mm x 150mm	22500	0.5	9.300	2,755.6	480	21.33
10%	150mm x 150mm	22500	0.5	9.050	2,681.5	475	21.11
20%	150mm x 150mm	22500	0.5	7.500	2,222.2	250	11.11
30%	150mm x 150mm	22500	0.5	7.100	2,103.7	135	6.00

Table 10. Results obtained for cube strength of cubes for each curing periods

Curing period	0%	10%	20%	30%
7 days	14.44	13.56	6.67	5.11
14 days	15.56	15.20	9.24	5.42
21 days	17.42	17.11	10.13	5.78
28 days	21.33	21.11	11.11	6.00

**Fig. 3. Surface plot representation of cube strength against curing periods**

3.3 Workability Results

Workability implies the ease with which concrete mix is handling and it can be determine by slump test. Slump test as for [11] is followed, the used of slump core and tamping rod. The Table 11 below shows the workability of each mix of concrete varying the percentage of Cow Dung Ash with the highest workability value of 100mm recorded for 30% of Cow Dung Ash in cement.

Table 11. Workability result of CDA

0% of CDA in cement	Slump (mm)
0%	40
10%	48
20%	80
30%	100

3.4 Consistency Limit Results

Consistency limit is basic aims to find out water content require to produce a cement paste of standard consistency as specified by the [12]. The Table 12 below showed the results obtained by varying the percentage of Cow Dung Ash added in as cement replacement with the highest value recorded for 30% Cow Dung Ash of 0.78 consistency limit.

Table 12. Consistency limits result of CDA

0% of CDA in cement	Consistency limit
0%	0.34
10%	0.46
20%	0.62
30%	0.78

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

From the analysis of the result, one can rightly conclude as follow:

- ✚ Cow Dung Ash concrete can be made to perform well in certain floor and wall applications when a ten percentage (10%) only it is added.
- ✚ The Cow Dung Ash requires more quantity of water as the percentage increases in the concrete, therefore it has a serious limitation that must be understood before it is put to use.
- ✚ The Cow Dung Ash has an advantage that offers lightness of weight that makes it useful construction material.

4.2 Recommendations

The following recommendations below is based on the outcome from the research and practical work been carried out as highlighted in the result presented in chapter Four.

- ✚ Cow Dung Ash concrete is recommended for use only when a ten percentage (10%) of Cow Dung Ash is added. While the concrete is suitable for use on certain floor and wall that will not be subjected to heavy load or structures that are of temporary use.
- ✚ Cow Dung Ash concrete is not to be use in a water accumulated area or for structures that are related to water.
- ✚ Cow Dung Ash concrete of high percentage over 10% are not suitable for concrete production due to the increase in the ash content.
- ✚ In general Cow dung Ash concrete is not suitable for use where high structural strength is required or where it would be subjected to heavy traffic and several abrasive actions.

COMPETING INTERESTS

Authors declare that there are no competing interests.

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